SMALL-SIZE EXPLOSIVE GAS MEASURING SENSOR MIPEX-02-X-X-X.1 X

USER MANUAL

ESAT.413347.005 UM

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Document revisions

Rev.	Date	Common changes
1.34	16 July 2014	Released version
2.0	27 August 2015	Formatting. Typical sensor sensitivity for different hydrocarbons. Description of RX code. Dust filter specification.

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List of abbreviations:

CGM – Control Gas Mixture;
EMI - Electromagnetic Interference;
LEL – Lower Explosive Limit;
NDIR - Non-Dispersive Infra-Red;
UART - Universal Asynchronous Receiver/Transmitter.

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INTRODUCTION

MIPEX-02-X-X-X.1 X (hereinafter, sensor or MIPEX-02) is the gas sensor, which is intended for automatic continuous measurement of concentration of hydrocarbons in explosive areas and carbon dioxide. The sensor is used for gas detection in atmosphere.

Sensor can be used as part of gas-analyzing equipment of groups I and II according to IEC 60079-0 in the explosion-hazardous zones of classes 0, 1, 2 according to IEC 60079-10-1, and Class I, Division 1 according to UL Std. 913, CAN/CSA Std. C22.2 No.157-92.

Optosense LLC reserves the right to update and change current user manual in parts excluding intrinsic safety parameters and accompanied information specified below.

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1. DESCRIPTION

The principle of sensor operation is based on NDIR technology.

Infrared radiation of the LED passed through the measuring gas diffusion cell and reaches the two of photodetectors, one of which detects radiation in the wavelength range of 3.25 to 3.45 μm only, while the other one detects radiation in the wavelength range of 3.45 to 3.7 μm. The analyzed gas that is present in the measuring cell absorbs radiation of the operating wavelength (λo) and does not affect radiation of the reference operating wavelength (λr). The amplitude Io of the light-sensitive cell operating signal changes upon changing concentration in accordance with equation:

$$Io/Ir = \exp\{-[K(\lambda o) - K(\lambda r)]CL\}; \quad (1)$$

where:

K (λ) – coefficient of absorption at a given wavelength;

L – optical length of cell;

C – measured concentration of gas;

Io, Ir – amplitude of signals at light-sensitive cell.

The concentration of gas is:

$$C = -Ln\,(Io/Ir)/(L\,[K\,(\lambda o) - K\,(\lambda r)]); \quad (2)$$

Using differential dual wavelength method allows eliminating influence of water vapor, contamination of optical elements and other non-selective hindrances affecting both channels similarly.

The sensor structure contains an optical cell with a mirror system, infrared light-emitting diode (LED), LED driver, receivers of Signal and Reference channels, analog amplifiers, microcontroller and supply voltages unit.

The microcontroller of the sensor performs:

- storage of unique calibration constants;
- calculation of gas concentration based on measured results;
- communication via UART output interface.

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2. TECHNICAL SPECIFICATIONS

Table 1. Technical specification (available options see Appendix A).

General	**Gas sampling method:**		Diffusion
	Operating principle:		Non-Dispersive Infra-Red (NDIR)
	Target gas		CH_4
			CH_4 /CH_4 +C_2H_6
			C_3H_8
			CO_2
	Operating, storage and transportation conditions:	**Relative humidity, %**	up to 98
		Atmospheric pressure, kPa	80-120
		Operating temperature*, °C	-55... +60
	Temperature range*, °C		-10… +40
			-40… +60
			-20… +50
	Overall dimensions, mm		ø20x16.5 without pins (standard and plastic versions)
			ø22x16.5 without pins (fast response versions)
	Pins length, mm		4,6
			5.75
	Weight, g		16,6
			15,5
			5,5
	Housing		Stainless steel (standard and fast response versions)
			Plastic
	MTBF, years		10
	Ingress protection (IP) rating		20 (without dust filter)
			54 (with dust filter)
Measurement	**Measurement range, % Vol**		0-1.5
			0-2.5
			0-5
			0-100
	Accuracy (UART data)		Up to 0.05% Vol or 5% of indication for CO2 and C3H8 Up to 0.1% Vol or 5% of indication for CH4
	Response time (T90), s		10
			20
			30
			60

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Electrical	**Supply Voltage Range:**	+3.0… +5.0 VDC
	Output signal	digital UART
	Power consumption, mW	<5
	Warm-up time (not more), min	2
	Degree of personal protection against electrical shock caused by the sensor	meets the requirement of class III GOST 12.2.007.0
Marking and standards compliance		**Ex ia I U/Ex ia IIC U.** acc. to ГОСТ Р МЭК 60079-0, ГОСТ Р МЭК 60079-11, ТР ТС 012/2011
		Ex ia I Ma/Ex ia IIC Ga. acc. to IEC60079-0, IEC60079-11, IEC60079-26. -55^0 ≤ Ta ≤ +60 ^{0}C
		IM 1/II 1 G Ex ia I Ma / Ex ia IIC Ga. acc. to EN60079-0, EN60079-11, EN60079-26. -55^0 ≤ Ta ≤ +60 ^{0}C
		RECOGNIZED COMPONENT Intertek 4004454 **Class I,Division 1,Group A,B,C,D** CONFORMS TO UL Std.913,60079-0,60079-11 CERT. TO CAN/CSA Std.C22.2 No. 157-92

* Term **operation temperature** means the ambient temperature where the sensor can be used safely, but the sensor accuracy supported only in **temperature range** (see **Table 3** and **Table 5**).

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3. INTRINSIC SAFETY

Combined intrinsically safe parameters of sensor circuits are as follows:

IECEx/ATEX: Ui = 5.0V, Ii = 450mA, Pi = 0.25W, Ci = 38.8µF, Li = 0 mH.

CAN/CSA: Vmax = 5.0V, Imax = 450mA, Pmax = 0.25W, Ci = 38.8µF, Li = 0 mH.

It is allowed to connect the sensor only to intrinsically safe circuits with the rated direct current output voltage (U0) within the range of not less than 3 V and not more than 5 V, with the output power (P0) - not less than 0.02 W and not more than 0.25 W.

The gas-analyzing equipment, which is used with MIPEX-02, must meet the requirements of IEC60079–0, IEC60079–11, IEC 60079-14 and have parameters conforming the MIPEX-02 intrinsic safety pointed above.

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4. PRECAUTIONS

- Inspection and maintenance of the sensor should be carried out by suitably trained personnel in accordance with the applicable code of practice (e.g. EN 60079-17).
- Any person who have studied this UM, have been briefed on safety precautions when operating electrical equipment intended for operation in the explosion-hazardous zones in the established order, is admitted to operate the sensor.
- Do not use damaged sensor. Unauthorized repair of the sensor is not allowed.
- It is strongly prohibited to discharge the control gas mixture (CGM) to the atmosphere during the sensor calibration.
- Do not allow the contact of the sensor with aggressive substances e.g. acidic liquids or gases that might attack metals, or solvents that might affect polymeric materials.
- The sensor does not contain any poisons and other harmful substances that might be released from the sensor during its operation. Risk to humans and environment does not exist.

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5. INSTALLATION AND SERVICES

- Models MIPEX-02-X-X-3.1 X are potential electrostatic charging hazard – clean them with a damp cloth only. Take it into account during installation and operation of the sensor in end-user equipment.
- The MIPEX-02-X-X-1.1 X and MIPEX-02-X-X-2.1 X models of the equipment were tested and found to hold 17.4pF maximum capacitance.
- Connection should be made via PCB sockets. Soldering to the pins will seriously damage the sensor.
- Excessive force on sensor housing is not allowed. For the metal housing - no more than 2 MPa applied to reflecting cover center or on at any point of middle part side surface and no more 100 MPa applied to boundary of reflecting cover. For the plastic housing - no more than 20 kPa applied to reflecting cover center or on at any point of side surface and no more 2 MPa applied to boundary of reflecting cover.
- Metrological properties are not supported in ambient temperature gradient faster than 0.6 ^{0}C/min.
- Set manual zeroing procedure after continues storage or transportation.

5.1 Preparation

5.1.1 If the sensor has been kept in the transportation package at temperature lower than 0^{0}C, hold it at temperature of 10–35 ^{0}C for at least one hour.

5.1.2 Remove the packing. Check presence of the certification marking, ensure absence of mechanical injuries.

5.2 Installation

Use intrinsic safety connection (see Appendix B for details).

5.2.1 Use the following recommended sockets for the sensor connection or similar:

- Cambion 450-3729-01-06-00;
- Harwin H3183-05;
- Harwin H3182 (for the MIPEX-02-X-X-X.1 A modification).

Sensor pinout is shown in Fig. 1 of Appendix A.

5.2.2 Provide intrinsically safe power supply to the sensor from power sources featuring nominal range of output DC voltage of not less than 3 V and not more than 5 V, output power (P0) – not less than 0.02 W and not more than 0.25 W in accordance with requirements of standards IEC 60079–0:2004, IEC 60079–11:2006.

5.2.3 The transceiver of UART interface should meet the requirements of standards IEC 60079–0, IEC 60079–11.

Communication parameters of UART- transceiver are following:

- HIGH logic level for transmit line **TxD** is 2.8V;

- HIGH logic level for receive line **RxD** should be in range between 2.8V and 3.3 V;

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- LOW logic level 0.9 V;
- Maximum output current of UART not more than 25 mA.

- MIPEX-02 has pulsing power consumption. Maximum current might shortly rise up to 10 mA during 10 ms pulse length. Average consumption is less than 1 mA (see Fig. 8).
- In case if the sensor sends response for the commands via UART maximum current consumption might rise up to 10 mA for 60 ms.
- Since the power is supplied, during 40s the sensor does not return the concentration value (the value is being displayed as "-1"). After that sensor starts to transfer measured values.
- Please note that if the dust filter from sensor's kit was attached, then **ZERO2** command must be send after warm-up time.
- Sensor updates information about concentration approx. every 1.3 sec. Sending commands more often than 1 time per sec (sampling rate over 1Hz) is not recommended, otherwise the temperature sensor accuracy comes down.

5.3 Proper use

It is recommended to use filter to protect the optical components of the sensor from dust, excess moisture and other factors that could affect on readings accuracy. Take measures for sensors dust protection in the equipment with forced gas pumping. A regular monitoring of the filter and it's replacement is necessary (filter installation – see Appendix E).

The setting of zero and calibration of the sensor is performed in the course of the primary installation into a gas analyzer as well as annually during preparation to conducting a check. In any cases the setting zero should be done before calibration. Methods of setting zero of the sensor and re-calibration are given in Appendix D).

The sensor outputs information about measured concentration value though the digital serial interface UART. Data communication protocol is given in Appendix C.

The sensor is designed for continuous operation.

There is self-testing algorithm inside the firmware code.

Since 24.2 firmware version there is additional mode of low power consumption (to set low power mode see C.3.2 of Appendix C). In low power mode sensor consumption is not more than 1.8 mW, but performance could be deteriorated.

Low power mode could be used as explosive gas indication mode even with deep battery discharge in device.

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6. STORAGE AND TRANSPORTATION

The transportation of the sensors should be performed by all means of transportation in covered transportation vehicles as well as in the heated pressurized plane compartments in accordance with the rules of cargoes transportation effective for the respective type of transportation.

The sensors in the Manufacturer's package should be kept in the Supplier's and Customer's storages under storage conditions pointed in Table 1. The atmosphere of storage premises should be free from harmful admixtures provoking corrosion.

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7. WARRANTY

The Manufacturer guarantees compliance of the sensors with specifications and requirements stated in this UM if Customer meets conditions of operation, transportation and storage.

During the warranty period, Customer has the right to get replace or repair of all the products that, according to its unquestionable valuation, are found to be defective, if defect is due to a fault of Manufacturer.

The warranty period is 24 months since the date of sensor shipment to a Customer. The date of shipment is registered in the ESAT.413347.005 PS datasheet.

Manufacturer is not responsible for the sensors failure and warranty is void in case of:

- violations of conditions of operation, transportation and storage stated in UM;
- sensor has marks of unauthorized repair;
- mechanical damages, appeared after handover the sensors to Customer, effect of temperature and pressure beyond conditions, chemical erosion, ingress of foreign substances inside the body of the sensor;
- defects due to electrical interface unspecified by UM and other documentation conveyed to the Customer;
- defects due to force majeure circumstances, disastrous occurrences, intended or reckless act of Customer or third party;
- defect or failure due to installing, damaging, changing or erasing of sensors firmware or changing sensors settings because of misuse of service codes via UART.
- defect or failure due to using power or signal cables unspecified by technical regulations and standards or operating the sensor with EMC influences exceeds maximums specified in IEC 61000-4-3, class II.

Replacement or repair of defective sensor does not lead to setting a new warranty period.

The Manufacturer is not responsible for possible damages, direct or indirect inflicted to people or properties if this is happened in case of repair, storage and transportation rules violation or due to purport or reckless act of Customer or third party. The Manufacturer does not respond as well for possible damages, direct or indirect inflict to appropriate equipment as the result of change, damage or data loss.

The warranty repair or replacement is effecting in site of Manufacturer or designated representative.

Every shipping and packaging charge and any other incidental expenses if the products must be returned to Manufacturer will be at the Customer’s own risk and charged to them.

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8. CONTACTS

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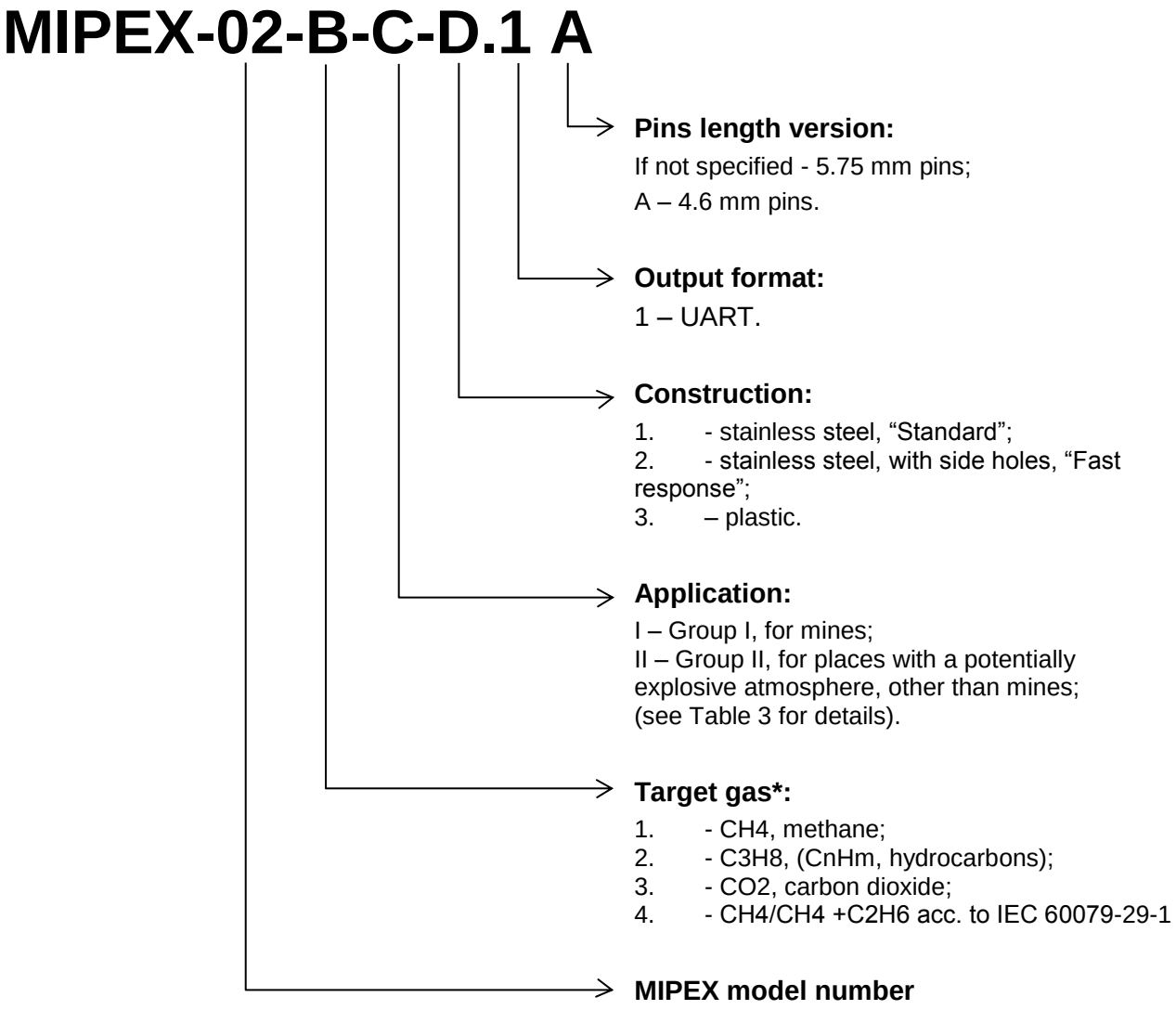
Appendix A. Sensor types and characteristics.


MIPEX-02-B-C-D.1 A
Pins length version:
If not specified - 5.75 mm pins;
A – 4.6 mm pins.
Output format:
1 – UART.
Construction:
1. - stainless steel, “Standard”;
2. - stainless steel, with side holes, “Fast response”;
3. – plastic.
Application:
I – Group I, for mines;
II – Group II, for places with a potentially explosive atmosphere, other than mines;
(see Table 3 for details).
Target gas*:
1. - CH4, methane;
2. - C3H8, (CnHm, hydrocarbons);
3. - CO2, carbon dioxide;
4. - CH4/CH4 +C2H6 acc. to IEC 60079-29-1
MIPEX model number

* Term **target gas** means the model of the LED and photodiode with the spectral range adjusted for best gas detection. Term **calibration gas** – is the gas mixture used for the sensor calibration.

There is an additional **RX** code presented on the sensor label. The code explains application properties (see Table 3 for details):

R – calibration gas and range;

X - temperature class and accuracy.

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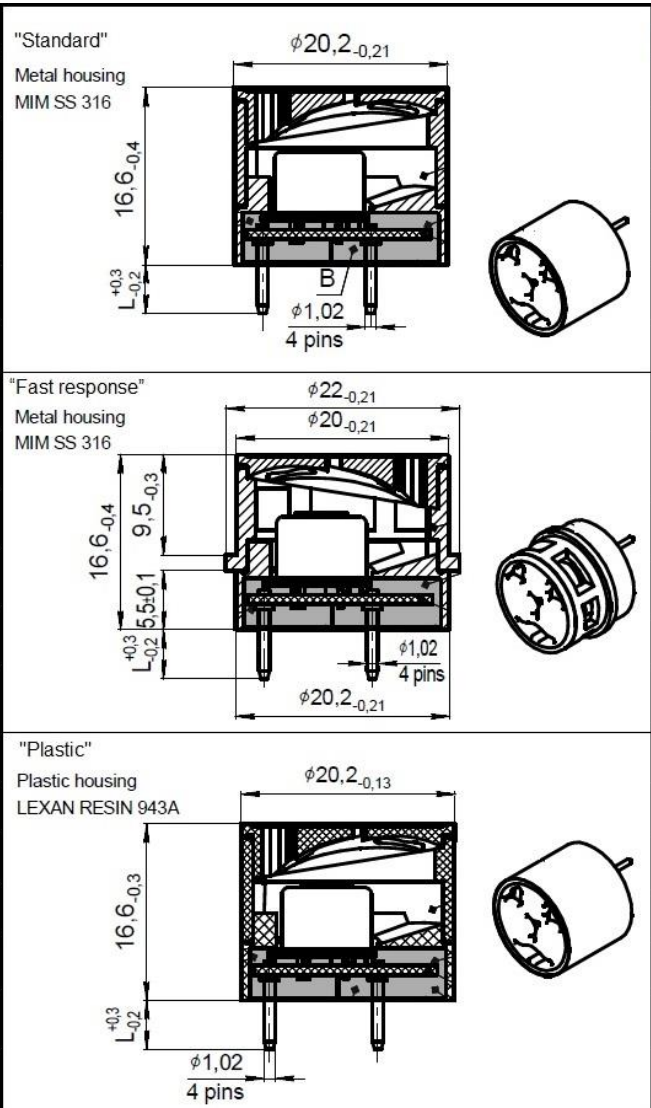
Table 2. MIPEX-02-X-X-X.1 X types and overall dimensions.

Sensor type MIPEX-02-X-X-X.1	Target gas	Weight,g
1-I-1	CH_4	16,6
1-II-1	CH_4	16,6
2-II-1	C_3H_8	16,6
3-I-1	CO_2	16,6
3-II-1	CO_2	16,6
4-I-1	CH_4/ $CH_4+C_2H_6$	16,6
1-I-2	CH_4	15,5
1-II-2	CH_4	15,5
2-II-2	C_3H_8	15,5
3-I-2	CO_2	15,5
3-II-2	CO_2	15,5
4-I-2	CH_4/ $CH_4+C_2H_6$	15,5
1-I-3	CH_4	5,5
1-II-3	CH_4	5,5
2-II-3	C_3H_8	5,5
3-I-3	CO_2	5,5
3-II-3	CO_2	5,5
4-I-3	CH_4/ $CH_4+C_2H_6$	5,5
Pins length L - 5,75 mm		



Sensor type MIPEX-02-X-X-X.1 A	Target gas	Weight,g
1-I-1	CH_4	16,5
1-II-1	CH_4	16,5
2-II-1	C_3H_8	16,5
3-I-1	CO_2	16,5
3-II-1	CO_2	16,5
4-I-1	CH_4/ $CH_4+C_2H_6$	16,5
1-I-2	CH_4	15,4
1-II-2	CH_4	15,4
2-II-2	C_3H_8	15,4
3-I-2	CO_2	15,4
3-II-2	CO_2	15,4
4-I-2	CH_4/ $CH_4+C_2H_6$	15,4
1-I-3	CH_4	5,4
1-II-3	CH_4	5,4
2-II-3	C_3H_8	5,4
3-I-3	CO_2	5,4
3-II-3	CO_2	5,4
4-I-3	CH_4/ $CH_4+C_2H_6$	5,4
Pins length L - 4,6 mm		

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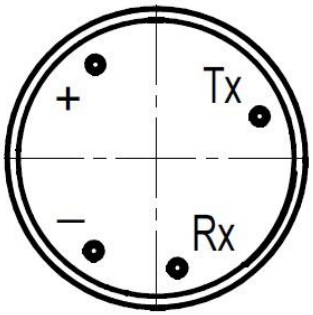

Pin	Circuit name
Tx	Communication,TxD output
Rx	Communication,RxD input
+	Power supply "+"
-	Power supply "-"

Fig. 1. Sensor pinout.

Table 3. Individual specifications of the sensor (RX code).

Target gas	Calibration gas	Measurement range	RX code (marking)	Temperature range, ^{0}C	Application
CH4 or CH4/CH4+C2H6	CH4	0-2.5 % Vol	00	-10… +40	I
		0-5 % Vol	10		
		0-100 % Vol	20		
CO2	CO2	0-1.5 % Vol	30		
CH4 or CH4/CH4+C2H6	CH4	0-2.5% Vol	01	-40… +60	II
		0-5 % Vol	11		
		0-100 % Vol	21		
CH4 or C3H8	C3H8	0-1.5 % Vol	61		
		0-2.5 % Vol	71		
CH4 or CH4/CH4+C2H6	CH4	0-2.5% Vol	02	-20… +50	
		0-5 % Vol	12		
		0-100 % Vol	22		
CO2	CO2	0-1.5 % Vol	32		
CH4 or C3H8	C3H8	0-1.5 % Vol	62		
		0-2.5 % Vol	72		

Typical sensor sensitivity to other hydrocarbons is shown on Fig. 2, Fig. 3 and Fig. 4.

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Table 4. Response time of the sensors.

Construction	Target gas	Max. response time t(90), sec
stainless steel, “Standard” and plastic	CH4	30
	CH4/CH4+C2H6	
	C3H8	
	CO2	60
stainless steel, with side holes, “Fast response”	CH4	10
	CH4/CH4+C2H6	
	C3H8	
	CO2	20

Table 5. General sensor accuracy* depends on calibration gas

Calibration gas	Accuracy over temperature range	Additional pressure error	Additional humidity error
CH4	±0,1%Vol. or ±5% of indication in range +20…+25°C; ±0,2% Vol. or ±10% of indication in range –10…+20°C and +25…+40°C; ±0,4% Vol. or ±20% of indication in range -40…-10°C and +40…+60°C.	±0,2% Vol. or ±30% of indication from 100kPa (test: 80kPa, 100kPa, 120kPa)	±0,2 % Vol. or ±15 % of indication from the indication at adjustment at 40 °C (test: 20 %RH, 50 %RH,90 %RH)
CO2, C3H8	±0,05% Vol. or ±5% of indication in range +20…+25°C; ±0,1% Vol. or ±10% of indication in range –10…+20°C and +25…+40°C; ±0,2% Vol. or ±20% of indication in range -40…-10°C and +40…+60°C.	±0,1% Vol. or ±30% of indication from 100kPa (test: 80kPa, 100kPa, 120kPa)	±0,1 % Vol. or ±15 % of indication from the indication at adjustment at 40 °C (test: 20 %RH, 50 %RH,90 %RH)

*Table shows the general accuracy, but individual sensor accuracy depends on RX characteristic and limited by the **temperature range** (see Table 3).

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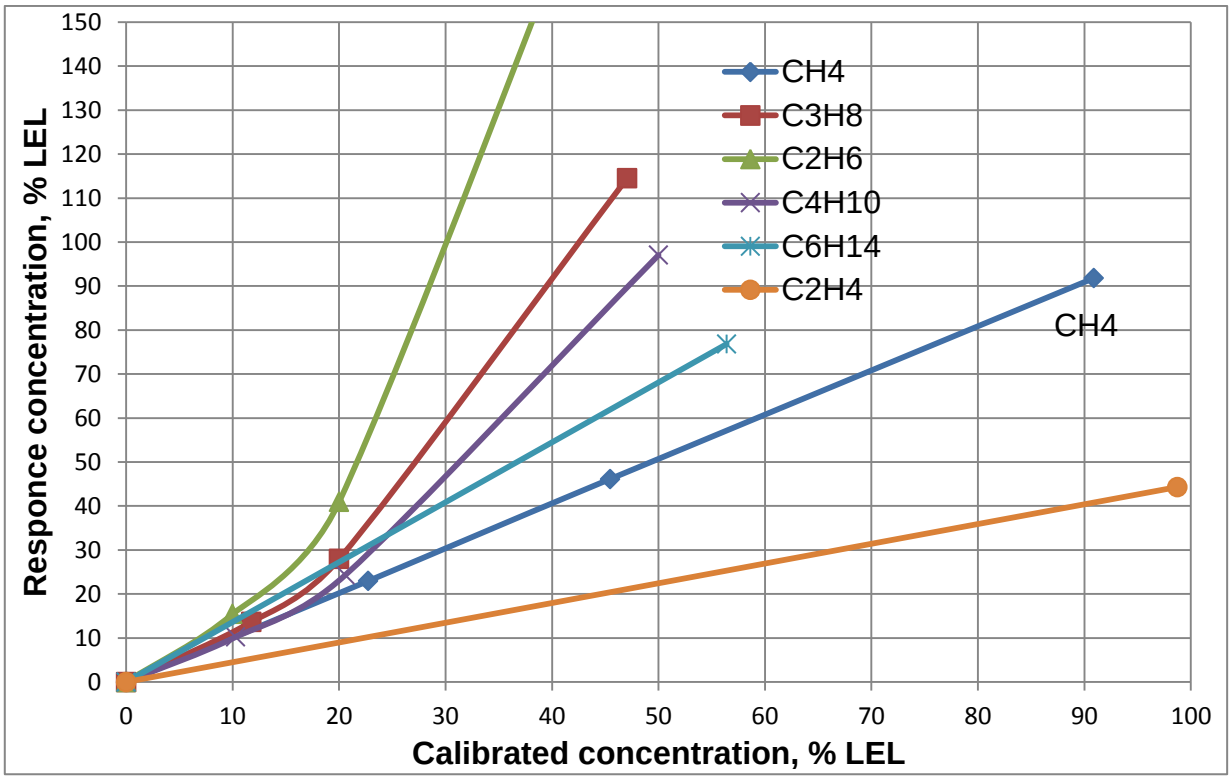

Fig. 2. Typical sensitivity of MIPEX-02-1-X-X.X X (target and calibration gases – CH4) to other hydrocarbons.

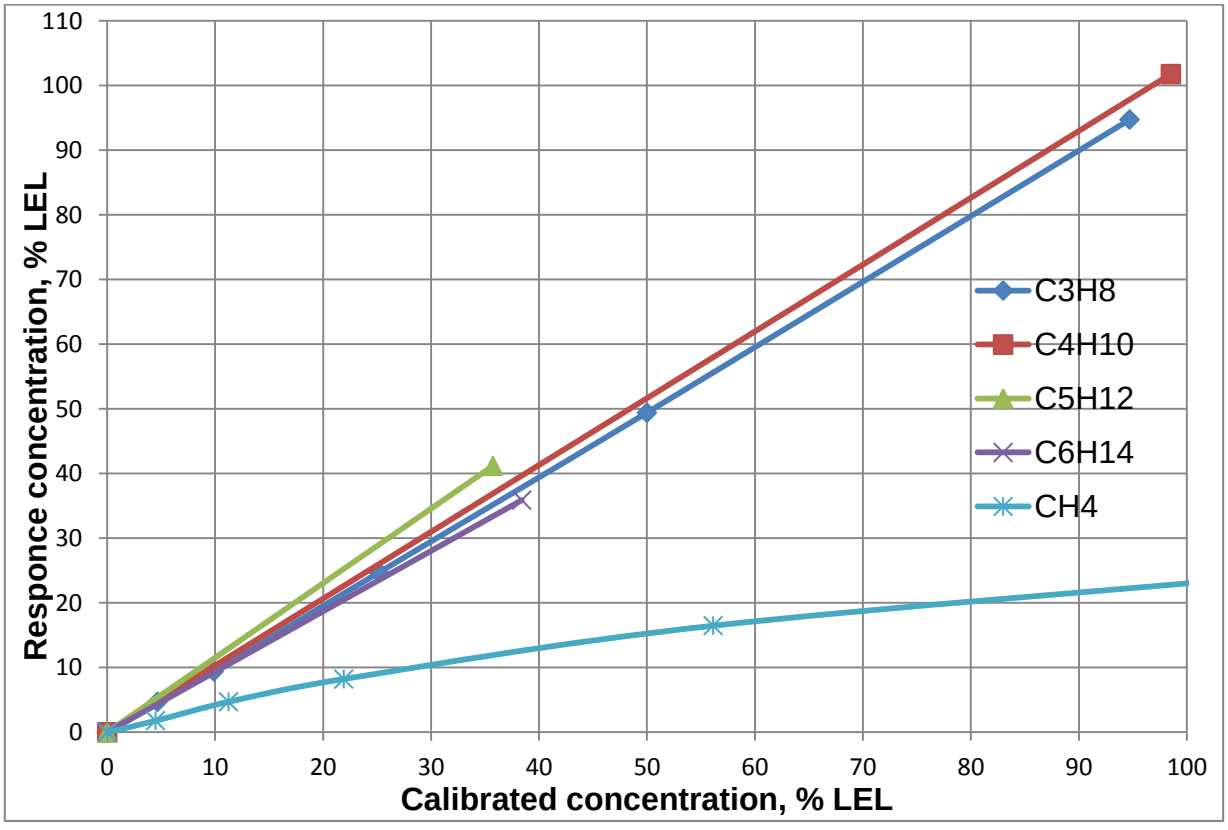

Fig. 3. Typical sensitivity of MIPEX-02-1-X-X.X X(target and calibration gases – C3H8) to other hydrocarbons.

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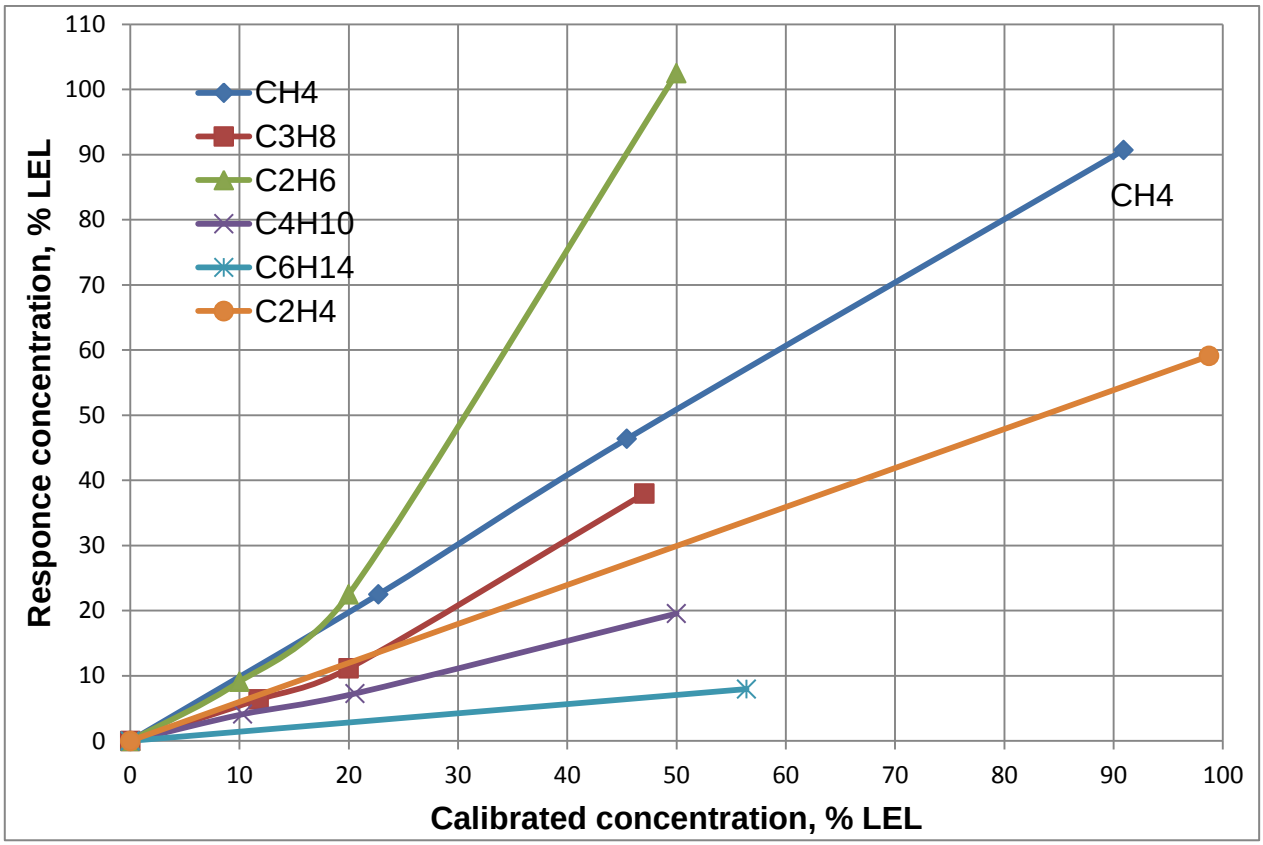

Fig. 4. Typical sensitivity of MIPEX-02-4-X-X.X X(target gas - CH4/CH4+C2H6, calibration gas – CH4) to other hydrocarbons.

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Appendix B. Connection diagram.

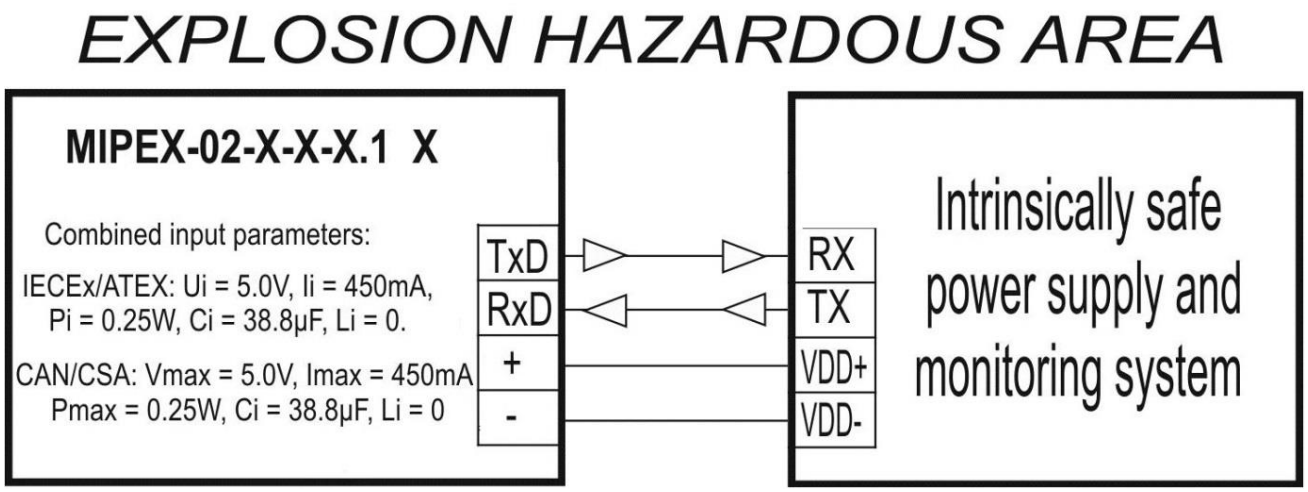

Fig. 5. Connection diagram for MIPEX-02-X-XX-X.1

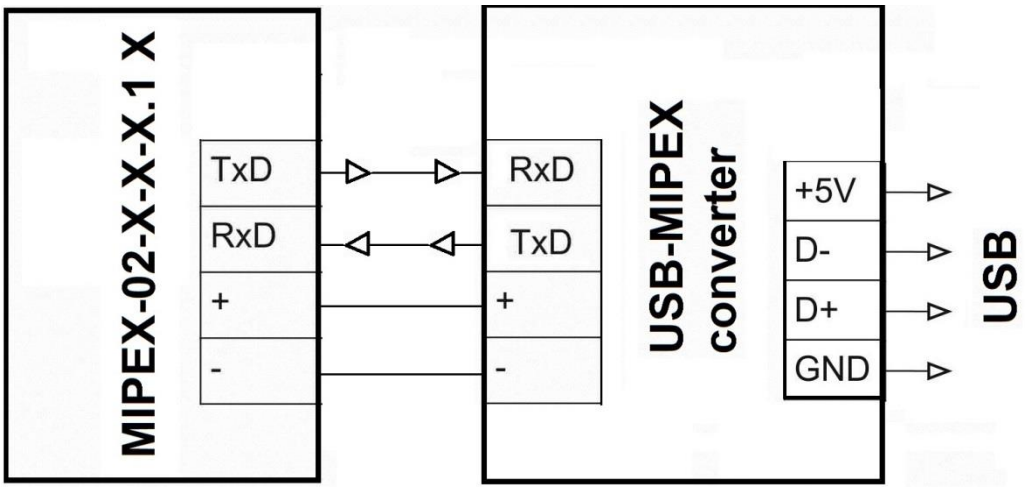

Fig. 6 Connection diagram for MIPEX-02 with USB-MIPEX converter during testing.

In Fig. 7 presented an example of sensor connection to “ia” intrinsic safety with the following characteristics: R value between 25…30Ohm, C = 20uF or over. For any other R more than 30Ohm, use the next equipment to found a minimum necessary capacitance: C(uF) = 2/3*R(Ohm).

For increased input power voltage upper than 5V it is needed to recalculate minimum allowable resistance which will completely consistent for our explosion safety parameters.

In very low power applications it is possible to reduce leakage current through the diodes using a micropower shunt voltage reference instead such as LM4040 or similar, protected against reverse voltages by using Schottky diodes.

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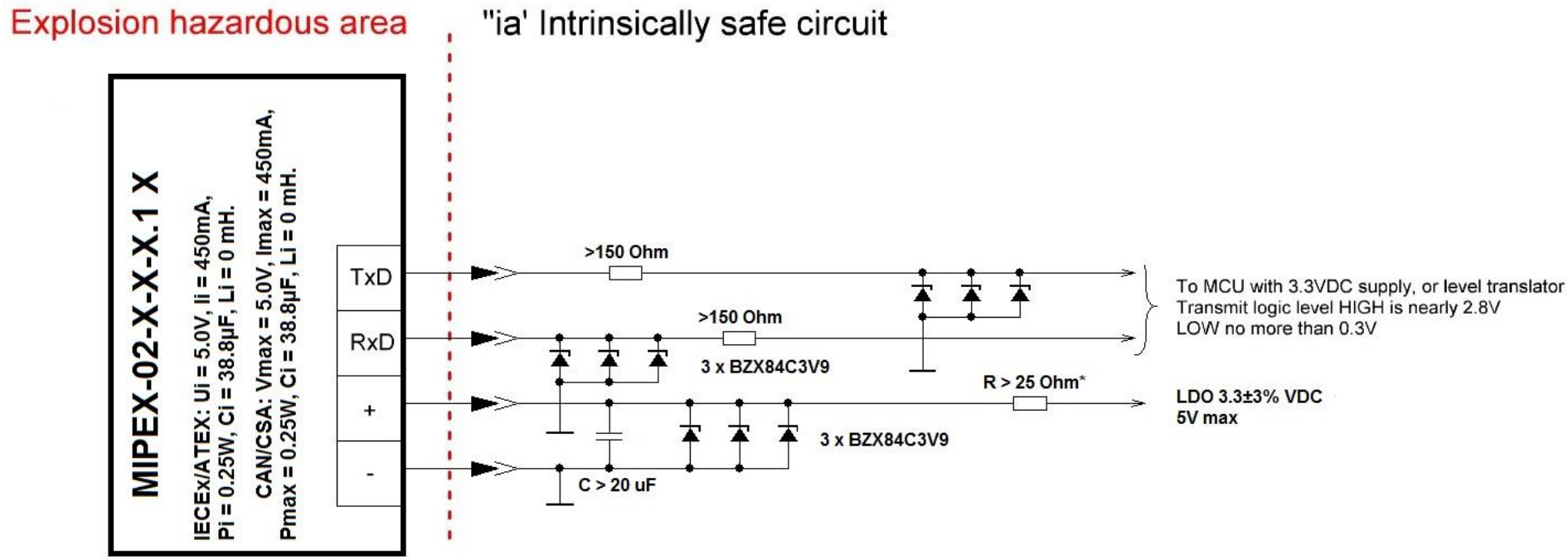
Explosion hazardous area
"ia' Intrinsically safe circuit
MIPEX-02-X-X-X.1 X
IECEx/ATEX: Ui = 5.0V, Ii = 450mA,
Pi = 0.25W, Ci = 38.8µF, Li = 0 mH.
CAN/CSA: Vmax = 5.0V, Imax = 450mA,
Pmax = 0.25W, Ci = 38.8µF, Li = 0 mH.
TxD
RxD
+
-
>150 Ohm
>150 Ohm
3 x BZX84C3V9
R > 25 Ohm*
3 x BZX84C3V9
C > 20 uF
To MCU with 3.3VDC supply, or level translator
Transmit logic level HIGH is nearly 2.8V
LOW no more than 0.3V
LDO 3.3±3% VDC
5V max

Fig. 7. Example of connecting sensor to "ia" intrinsic safety circuit.

Fig. 8 demonstrates the waveforms of typical MIPEX-02 current consumption and barrier voltage drop with the different values of R. If capacitor C = 20uF and resistor R = 30Ohm in power supply part of the diagram in Fig. 1, the output voltage of the barrier during the current pulses are not less than 3.1V, then MIPEX will work properly (without negative influence on performance). If capacitor C = 20uF and resistor R = 60 Ohm, the barrier output voltage falls below the minimum supply voltage 3.0V. In this case, the sensor might be unstable.

To prevent MIPEX-02 supply voltage decrease below 3.0V, use following recommendations:

- Increasing of barrier supply voltage.
- Increase the value of the capacitor in line: i.e. for R = 60 Ohm use capacitor value at least C (uF)~ 2/3 * 60 (Ohm) = 40 uF.
- Reduce the value of R (but not less than 25 Ohm, because of limitations Ui=0,25W with 5Vmax).

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Output current of TxD line and the leakage current through the protection diodes contribute to the voltage drop across the resistor R.

In too large output current in TxD circuit it is possible to get the peak output voltage of the barrier below 3.0V, which will cause incorrect operation of the sensor. To be completely sure, that sensor will be powered properly, we recommend to check supply voltage using oscilloscope while working with your device.

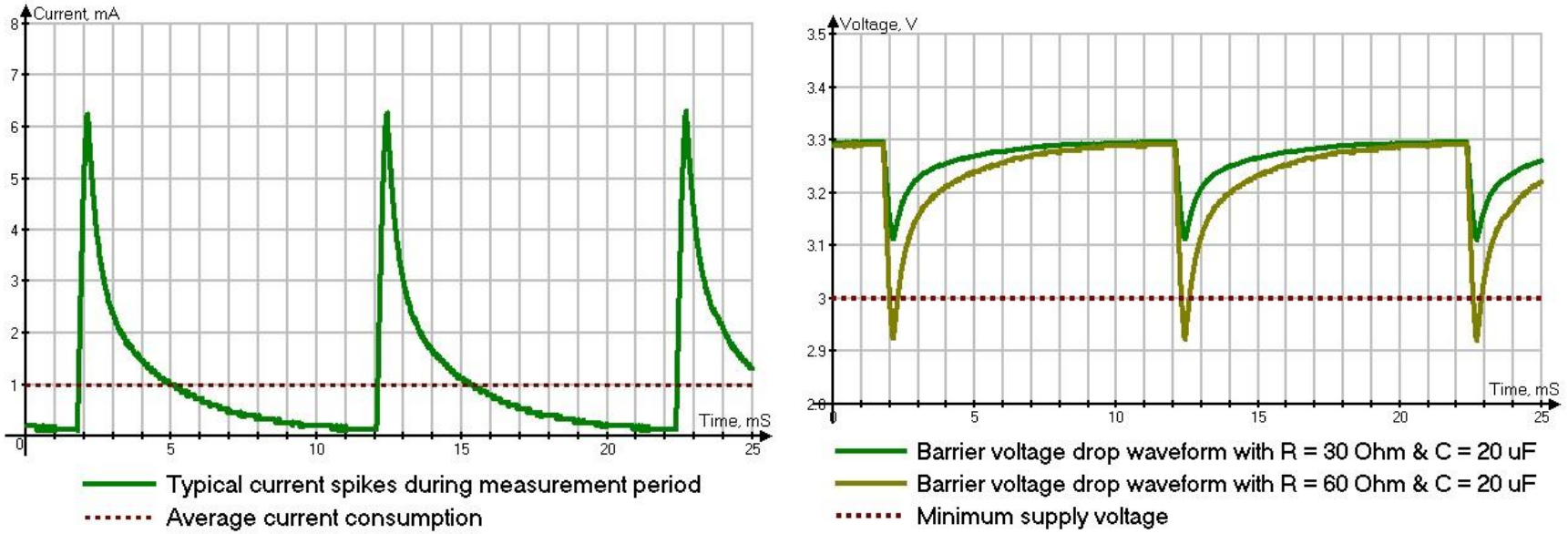
Current, mA
Time, mS
Typical current spikes during measurement period
Average current consumption
Voltage, V
Time, mS
Barrier voltage drop waveform with R = 30 Ohm & C = 20 uF
Barrier voltage drop waveform with R = 60 Ohm & C = 20 uF
Minimum supply voltage

Fig. 8. Diagrams of typical MIPEX-02 current consumption and barrier voltage drop.

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Appendix C. UART communication protocol.

Firmware release 25.6

Always check the command syntax before sending. The commands, other than specified in user manual are not allowed. Otherwise it might bring to malfunction of the sensor.

In earlier firmware versions some commands/modes are not available.

C.1. General information

- Sensor communication protocol provides data exchange based on “Request-Response” principle.
- Sensor has fix 9600 baud rate
- Electrical parameters of UART-transceiver are pointed in 5.2.3.

Data format: 8-bit message, 1 stop bit, no parity.
Frame format (if other is not specified):

- the symbols of commands are in ASCII,
- carriage return (CR) symbol must be after each command,
- all symbols in the commands must be sent in one word. Delay between symbols are not more than 40 ms.

The words of the response are separated with a tabulation symbol (09h) or space symbol (20h) (specified below for every command). For some commands request is not intended to answer according to following protocol. Sensor returns confirmation or rejection of command. Request on correct command with correct data returns command name with **OK** separated by (09h) or (20h). Request on correct command with wrong data returns command name with **FAULT** separated by (09h) or (20h). There is no reaction on wrong command.

C.2. Work modes

There are two modes of sensor’s work – **OEM** and **USER**. **OEM** mode is intended to display information and make calibrations and setup. **USER** mode is intended to display information only. Calibration in **USER** mode is unavailable.

Send command **UART?** to check current sensor mode (see Table 10).

C.3. Protocol commands

C.3.1. Operating commands

Data request commands are the basic sensor functionality and contained various combinations of parameters, such as concentration, temperature, sensor condition and status. The shortest command of the protocol is @. It includes the gas concentration only. The most detailed request is **F**, which contains a data, calculated during the sensor operating.

Detailed information about the operating commands is shown in Table 6.

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Table 6. Sensor operating commands

Command in OEM mode	Available in USER mode	Command name	Response	Description
@	Yes	Requests of concentration.	see Table 8	Response in HEX. The command @ is 16-bit concentration data. The lead byte **Conc1H** transmitted first, low byte **Conc1L** at the end of response.
@*X	Yes	Periodical request of concentration.	see Table 8	Response in HEX. The command **@*X** is initiate regular transmitting of gas concentration data to UART. Here **X** - is a value in range 0…9 (ASCII) proportion to standard operating period of the sensor (1.3 sec).
DATA	Yes	Request concentration readings.	ASCII 5-digits and 0Dh	The response is the concentration in %Vol * 100. i.e. response 00198 means 1.98%Vol.
DATAE	Yes	Request concentration, status byte and check sum.	HEX 4-bytes and 0Dh	Bytes #1…2 are the concentration data (similar to @-response), byte #3 is the status byte, byte #4 - **ControlSum^EveryByte**.
DATAE2	Yes	Request concentration, double status byte and check sum. Response in HEX.	HEX 6-bytes and 0Dh	Bytes #1…2 are the concentration data (similar to @-response), bytes #3…4 are the status bytes, byte #5 - **ControlSum^EveryByte**.
CCS	Yes	Request of concentration, temperature in Celsius degrees and status word.	**XXXXX YYYYY ZZZZZ**	**XXXXX YYYYY ZZZZZ** separated with space symbol (20h) in ASCII. **XXXXX** is gas concentration, **YYYYY** is temperature value in Celsius, **ZZZZZ** is the status byte (see Table 9)
CFS	Yes	Request concentration, temperature in Fahrenheit degrees and status word.	**XXXXX YYYYY ZZZZZ**	**XXXXX YYYYY ZZZZZ** separated with space symbol (20h) in ASCII. **XXXXX** is gas concentration, **YYYYY** is temperature value in Fahrenheit, **ZZZZZ** is the status byte.
CKS	Yes	Request concentration, temperature in Kelvin degrees and status word.	**XXXXX YYYYY ZZZZZ**	**XXXXX YYYYY ZZZZZ** separated with space symbol (20h) in ASCII. **XXXXX** is gas concentration, **YYYYY** is temperature value in Kelvin, **ZZZZZ** is the status byte.
CONST	No	Request of sensor constants.		The response includes the constants stored in sensor memory and used for troubleshooting. The response format available by request. See chapter C.5 for details.
CONST2	No	Request of sensor constants from the special memory space.		
F	Yes	Detailed information about working condition of the sensor.	see Table 7	Response on **F** command is 5 byte in ASCII separated by (09h).

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Table 7. Structure of F command response

Byte number	Byte data	Data description
1	0Eh	Special character
2-6	Termo	Sensor temperature in ADC readings
7	09h	Tabulation
8-12	<St>	Ratio Us/Uref with temperature index
13	09h	Tabulation
14-18	Us	Operating signal in ADC readings
19	09h	Tabulation
20-24	Uref	Reference signal in ADC readings
25	09h	Tabulation
26-30	Stz0	Ratio <Stz> with manual zeroing settings (ZERO)
31	09h	Tabulation
32-36	Stz	Ratio Stz0 with drift compensation algorithm
37	09h	Tabulation
38-42	Stzkt	Ratio Stz with coefficient of temperature sensitivity
43	09h	Tabulation
44-48	Conc	Concentration (according to a factory calibration)
49	09h	Tabulation
50-54	Conc1	Concentration scaled by user
55	09h	Tabulation
56-60	Status	Status word (see Table 9)
61	09h	Tabulation
62-71	Sn	Sensor serial number
70	09h	Tabulation
71	ControlSum	Checksum based on XOR
72	09h	Tabulation
73	0Dh	Carriage return

Table 8. Structure of @ and @*X commands

Command @ (40h 0Dh) response, byte number and data		Command @*x (40 2A x 0D) response, byte number and data		
1	2	1	2	3
Conc1H	Conc1L	@(40h)	Conc1H	Conc1L

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Table 9. Status word description

Status word	Status byte L (DATAE or DATAE2)	Status byte H (DATAE or DATAE2)	Description	Recommendation
00			Normal mode, static temperature	
10	Bit 0		Warm-up	Do not perform calibration.
11		Bit 0	Too many UART interruptions	Do not perform calibration or zeroing. Decrease request frequency.
21	Bit 4		Fast temperature change	Do not perform calibration or zeroing.
22	Bit 5		Sharp temperature change	Do not perform calibration or zeroing.
24	Bit 4	Bit 1	Fast temperature change + Zero shifts to negative values	Do not perform calibration or zeroing.
30	Bit 2		Low signals level	Do not perform calibration or zeroing. Measuring accuracy need to be additionally verified, once switching on of Bit 2 has been observed. Replace the sensor if Bit2 is on constantly (> 20 min).
31		Bit 1	Zero shifts to negative values	Using of dust filters is recommended to avoid moisture or dust inside sensor. In case of moisture ingress, unmounts sensor off device, then dry it during 4 hours minimum in warm dry location. Make zeroing procedure and performance check.
40	Bit 6		Out of operation temperature range	Check the ambient temperature.
50	Bit 1		Abrupt change of signal	Do not perform calibration or zeroing. Replace sensor, if bit1 is on constantly (> 20 min).
51			Complex status	Contact support for details
90	Bit 7		Firmware corruption	Contact support for details
1XX		Bit 2	Low power mode is on. XX- status word values similar for normal mode.	To achieve full compliance to declared specification turn on the standard mode

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C.3.2. Request commands of factory settings and properties.

The commands shown in Table 10 are used for sensor setup, check the factory settings and firmware update.

There is able to work with up to 256 sensors in one UART line. Use prefix **#XX** before any command to send commands to any sensor in one UART line. **XX** is a network hexadecimal address from 00 to FF.

Table 10. Setting commands

Command in OEM mode	Available in USER mode	Command name	Response	Description
LOWPW**x**	No	Setup power mode.	LOWPW**x** **OK**	**x** = 0 – normal mode of power consumption (**HI**), **x** = 1 – low power consumption mode (**LW**).
LOWPW?	No	Check the current sensor mode.	**HI** or **LW**	
OEM **XXXX**	Yes	Change mode from **USER** to **OEM.**	**USER** or **OEM**	**XXXX** is digital password. If the password not correct, sensor stay in current mode.
USER	Yes	Change mode from **OEM** to **USER.**	**USER**	
PASS **XXXX YYYY**	No	Password change.	PASS **XXXX YYYY OK**	**XXXX** is old password, **YYYY** is new password. By default the password is ‘’**0000**’’.
DATEZC **DD.MM.YY**	No	Write calibration date in format **DD.MM.YY.**	DATEZC **DD.MM.YY OK**	**DD** – day (1-31), **MM** – month (1-12), **YY** – year (00 – 99).
DATEZC?	Yes	Check calibration date.	**DD.MM.YY**	
CRC	Yes	Firmware integrity check, calculated according to CRC16 algorithm.	**CRC OK** and **XXXXX YYYYY OK**	After time-out during the calculations, not more than 1 sec). **XXXXX** – calculated checksum for current firmware, **YYYYY**– checksum stored in memory of the sensor. In case of malfunction, **XXXXX** and **YYYYY** values does not match together. Status word indicates 90 value if CRC mismatches.
ID?	Yes	Check identifier.	**TYPE SN RX SREV**	Returns summary info about type code, serial number, RX code and firmware version separated with space symbol.
INDSIG ON	No	Turn on negative shift indication in concentration readings.	ON	The command activates the possibility to show concentration shift to negative values. In case of using this command, response on concentration request is **-2** (status word 31) or **-3** (status word 24) in ASCII. It is not needed to activate mode after power reset.
INDSIG OFF	No	Turn off negative shift indication in concentration readings.	OFF	

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RT?	Yes	Check the type code (TYPE)	ASCII 5-byte and 0Dh	The response includes the sensor type data (MIPEX model, target gas, housing code and pinout code). The response format available by request.
RX?	Yes	Check the characteristics code (RX).	ASCII 2-byte and 0Dh	RX codes according to Table 3.
SRAL?	Yes	Check the sensor serial number (SN).	ASCII 8 byte and 0Dh	
SREV?	Yes	Check the firmware version.		Response includes the sensor model and current firmware version. For example: **MIPEX-2_25.4**
SREVH	No	History request of firmware updates.		The command response is the 10 latest firmware versions. Example of response – see chapter C.4.
USERDATA?	No	Display all data stored in memory.	Stacked 10 digits shows	There is ability to save up to 10 digits (0-99999) to flash-memory of the sensor. After firmware update from the 25.2 version, where this function is absent, all default values are «**67294**».
USERDATA **XX**?	No	Check data in the sensor memory.	Value from 00 to 09	Display the data saved in cell with **XX** number.
USERDATA **XX YYYYY**	No	Save data to the sensor memory.	**YYYYY**	Save **YYYYY** value to cell number **XX.**
NETON	No	Enable to storing network address	**NETON OK**	After turn off power, net address will be reserved.
NETOFF	No	Disable address storing.	**NETOFF OK**	After turn off power, net address will be erased (default 00 value).
!**	No	Check current network address.	**XX**	Response is network hexadecimal address
%XXYY	Yes	Set up network address.	**YY**	**XX** – old address, **YY** – new address.
UART?	Yes	Request current work mode.	**USER** or **OEM**	
UPLOAD	No	Switch the sensor to firmware update bootloader mode.	**U_OK**	See chapter C.4 for details.

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C.3.3. Sensor setting and calibration commands

The commands shown in Table 11 are used during sensor calibration. The procedure and used equipment described in Sensor zeroing.

Table 11. Calibration and zeroing commands

Command in OEM mode	Available in USER mode	Command name	Response	Description
AZERO ON	No	Turn on autozeroing algorithm.	**AZERO ON**	From the firmware ver.2x.6 introduced new autozeroing algorithm and the possibility to adjust the temperature coefficients by user. Autozeroing is embedded in self-diagnostics algorithm of the sensor. It starts after sensor is powered up. Self-diagnostics is operating during the sensor is on. If anyway, zero shift is observed, manual zeroing procedure is recommended.
AZERO OFF	No	Turn off autozeroing algorithm.	**AZERO OFF**	
AZERO?	No	Check current autozeroing status.	**AZERO ON** or **AZERO OFF**	
CALB **AAAA**	No	Span gas calibration.	**CALB AAAA OK** or **CALB AAAA FAULT**	**AAAA** is CGM concentration value in %Vol.*100. For example, **AAAA**=0198 corresponds to 1,98 %Vol. Entered value must not be different from current readings more than 20 times with regard to all units converted to %Vol. CGM concentration must be more than 0,2% Vol. If these conditions are not accomplished, sensor responds **CALB AAAA FAULT**. Scaling procedure should be used for following purpose: - Quick switch between readings in % vol. or % LEL. - Setup known cross-coefficients for measuring other heavy hydrocarbons gases (CnHm).
CALB1 **XXXXX**	No	Write scale coefficient for concentration for range 0-5% Vol. (CH4).	**CALB1 XXXX OK**	**XXXXX** – value of scale coefficient, 10000 corresponds to unitary coefficient.
CALB2 **XXXXX**	No	Write scale coefficient for concentration range 5-100% Vol. (CH4).	**CALB2 XXXX OK**	
CALB3 **XXXXX**	No	Write scale coefficient for whole concentration range 0-100% Vol. (CH4).	**CALB3 XXXX OK**	

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SETC **XXXXX**	No	One-point temperature calibration.	**SETC XXXXX OK**	**XXXXX** – temperature in Celsius degrees. With **SETC** command, sensor stores in memory the ambient temperature value. Also see **CCS**, **CFS**, **CKS** command description.
ZERO	No	Setting zero in current temperature.	**ZERO OK**	Command allows to set zero in different points of operating temperature range. See detailed procedure below.
ZERO **XXXXX YYYYY**	No	Manual setting of temperature coefficients.	**ZERO XXXXX YYYYY OK**	**XXXXX** – temperature data, **YYYYY** – signal ratio **<Stz>**.
ZERO2	No	Setting zero in whole operating temperature range.	**ZERO2 OK**	The command initiate calculation and store a unifying zero coefficient to the memory. In case of supplying this command, concentration **Conc** = 0, **Conc1** = 0, relation **Stz** is corrected to 10000 (see Table 7).
INIT	No	Restore to factory default.	**INIT OK** or **INIT FAULT**	The command is used in case of wrong sensor calibration or other improper actions over the sensor.

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C.4. Firmware update

- Firmware update must be proceed with accordance to following description. **Optosense LLC** disclaims all liability for sensor malfunction due to mistakes committed by user during firmware update.
- Firmware version 24.6 is compatible with previous version 24.2 for MIPEX-02-3-X-X.1 X (CO_2) only.
- Firmware version 25.6 is compatible with previous versions 25.2 and 25.4 for MIPEX-02-1-X-X.1 X (CH_4), MIPEX-02-2-X-X.1 X (C_3H_8), MIPEX-02-4-X-X.1 X (CH_4/CH_4 +C_2H_6) only.

The term «compatible» means that sensor performance as well as protocol commands of previous versions keeps unchanged after finishing of firmware update process.

To update sensor firmware use the following procedure and commands:

- Send **SREV?** command and check that current version is able to be updated. If firmware version is 25.4, make sure that sensor is in OEM mode by sending **UART?**.
- Send **UPLOAD** and receive **U_OK** response. Sensor switched to bootloader.
- Upload firmware to sensor memory. It is necessary to make “Erase pages” before loading application code. Page quantity corresponds to code file size in Kbytes.

Do not use “Mass erase” in bootloader, it will clear all memory and leads to sensor malfunction.

- Verify uploaded firmware code. Use “Read memory” command of bootloader.
- Turn off the power of sensor and then turn it on. If “Jump to user code” function has been used in bootloader mode to switch the sensor power is not necessary.

- Description and example of procedure using PC, MIPEX evaluation kit and STMicroelectronics flash loader software could be found in archive with new firmware.
- More details about algorithms and protocol in bootloader mode could be found in the documentation ***“AN2606 Application note STM32™ microcontroller system memory boot mode”***.
- For MIPEX-02-3-X-X.1 X (CO2) proceed sending **ZERO2** only with nitrogen feeding.

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C.5. Troubleshooting

In case of malfunctions or errors of sensor do following steps:

1. Send in OEM mode sequence of commands **F, SREVH, CONST**, **CONST2** in ASCII;
2. Save responses in log-file;
3. Send this log-file with comments via e-mail support@mipex-tech.com.

Example of log-file listing obtained by MIPEX ETS:

Port: COM3
SN: 08065278
Type: MIPEX-2_25.6
==========
Sending:
> #00UART?
<< OEM

> F
<< 01665 10042 08482 07981 10002 10000 10000 00000 00000 00000 08065278

> SREVH
<< MIPEX-2_2506
MIPEX-2_2504
MIPEX-2_0000
MIPEX-2_0000
MIPEX-2_0000
MIPEX-2_0000
MIPEX-2_0000
MIPEX-2_0000
MIPEX-2_0000
MIPEX-2_0000

> CONST
<< 10000 09829 10454 08035278 00000 001485 -00005 -00010 00200 01671 00772 01588 00020 00015 00120 00020 00060 0000000000 06900 00500 00800 08948 10000
00412 03400 00100 00200 10002

> CONST2
<< 10000 09829 10454 08035278 00000 001485 -00005 -00010 00200 01671 00772 01588 00020 00015 00120 00020 00060 0000000000 06900 00500 00800 08948 10000
00412 03400 00100 00200 10002

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Appendix D. Sensor zeroing and calibration.

1. Closing gas-sampling holes of the sensor impairs response time.
2. Do not zeroing under span gas concentration.
3. Recommended zero-gas is nitrogen or clean air (no impurities).
4. Always make manual zeroing after sticking (or removing) the dust filter on the sensor.
5. To achieve correct data during the tests, be sure there are no:
   - excessive force on sensor housing,
   - 100% humidity (dewpoint),
   - out of specified range of environmental pressure,
   - fast temperature change (more than 0.6 ^{0} C/min), dust (if dust filter is not used),
   - sensor rate no more than 1Hz.

The setting of zero and calibration of the sensor is performed in the course of the primary installation into a gas analyzer as well as annually during preparation to conducting a check. In any cases the setting zero should be done before calibration.

The devices given in Fig. 9 and the CGM are used in the course of conducting operations.

The operations on setting zero and calibration of the sensor shall be carried out by a qualified specialist outside of the explosion-hazardous zone at normal conditions.

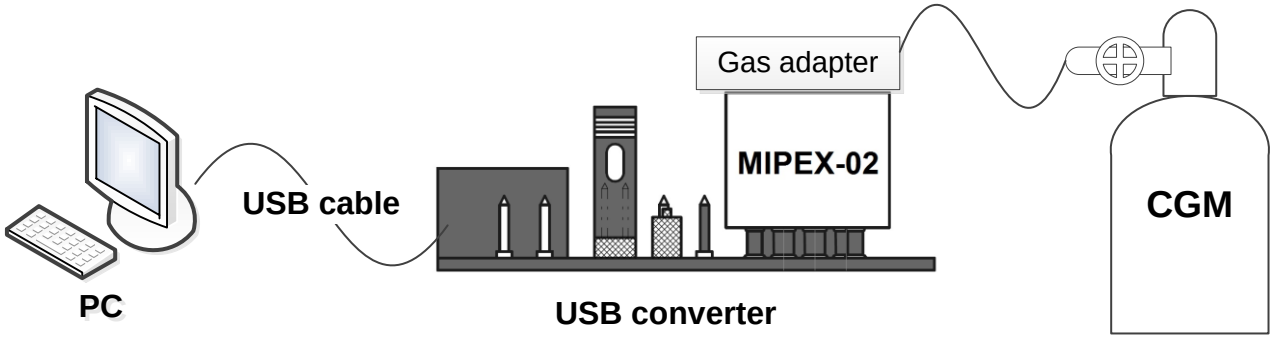

Fig. 9 Typical scheme of MIPEX-02 calibration

D.1. Zeroing

D.1.1. Autozero.

Autozeroing is embedded in self-diagnostics algorithm of sensor. It starts after sensor is powered up. Self-diagnostics is operating all along during the sensor is on. If anyway, zero shift is observed, manual zeroing procedure is recommended.

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D.1.2. Manual zeroing in whole temperature range.

1. Fill up the sensor with zero-gas.
2. Send **DATAE** and check, that status byte in response is 0.
3. Send **ZERO2** command in ASCII and check, that response is **ZERO2** OK.

D.1.3. Manual zeroing in different points of temperature range.

If zero shift appears in different temperature, use **ZERO** command with following recommendations.

Procedure is similar to manual zeroing in whole temperature range and consists **ZERO** command sending in various static temperatures, i.e. after status byte in response of **DATAE** is 0.

There are three ways to make this procedure:

One point zeroing. Send **ZERO** command in any static temperature. That is recommended to take a temperature point close to 23 ºC.

Three points zeroing. Taking one point at 23 ºC and two others close to edges of operating temperature range is recommended.

Multipoint zeroing. That is recommend to take one point at 23 ºC, two points at the edges of operating temperature range and some other intermediate points. Similar, 10-13 ºC - fold interval should be taken between each points.

Because of MIPEX-02-X-II-X.1 X temperature range could be divided on 8 interval, most time taking, but most precise procedure is 9-point zeroing.

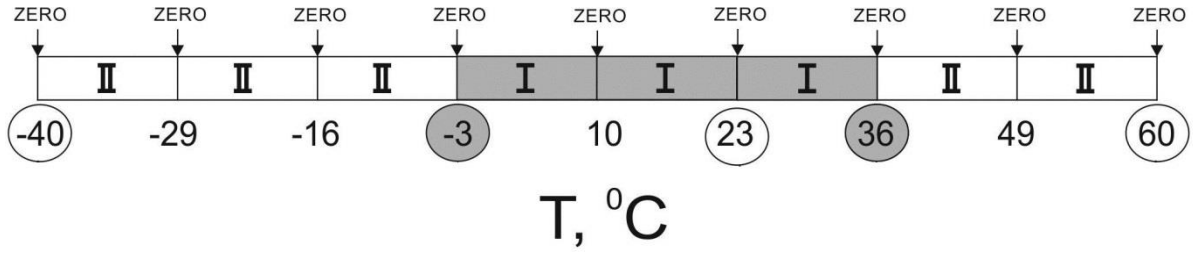

Fig. 10. Scheme of manual zeroing with ZERO command.

If the requirements to the sensor error are not fulfilled in accordance with Table 5, the procedure of setting zero and calibration shall be repeated. In case of a repeated non-compliance of the sensor readings to the value of concentration of CGM No.3, the sensor is subject to replacement and dispatching to the Manufacturer.

D.2. Scaling

Scaling procedure should be used for following purpose:

- Quick switch between readings in % vol. or % LEL.
- Set up cross-coefficients for measuring other hydracarbons gases, than calibrated one. Cross-coefficients can be requested as additional option by ordering. Please note, that accuracy in this case is lower than specified.
- There are two scale coefficients for CH4-sensors. First is for 0-5%Vol. range. Second is for 5-100%Vol. range.

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- Proceed operations pointed below as**, only if sensor has 0-100 % Vol. measuring range or up to 100%Vol. indication range.

Use the following sequence to make scaling:

1. Send **DATAE** and check, that status byte in response is “0”.
2. To set up the first coefficient send **CALB1 XXXXX** command in ASCII and check, that response is **CALB1 XXXXX OK**. Where **XXXXX** is scaling coefficient, i.e. 20000.
3. ** To set up the second coefficient send **CALB2 YYYYY** command in ASCII and check, that response is **CALB2 YYYYY OK**.

By default, scaling coefficients are **XXXXX**=**YYYYY**=10000, that means of no scaling. Do not apply span gas while scaling.

For example, if it is needed to get readings of CH4 in %LEL, normalized to 1000 (reading 1000 corresponds to 100% LEL of CH4) send **CALB1** 20000.

Use the following sequence to span gas calibration procedure:

1. Make Manual zeroing procedure.
2. Fill up the sensor with span gas in the range up to 5%Vol (recommended in mid of range, e.g. 2.5% Vol. CH4).
3. Wait until status byte becomes “0” and gas reading stabilized, sending DATAE commands and checking their responses.
4. Send **CALB AAAA** command in ASCII (43h; 41h; 4Ch; 42h; 20h; AAh; AAh; AAh; AAh; 0Dh in HEX), where **AAAA** is gas concentration, normalized to 1000 (i.e. **AAAA**=0250 for 2.5% Vol CH4). Span gas concentration must be more than 0.1% Vol. Otherwise the sensor will return FAULT in response. Check, that response is **CALB AAAA OK**.
5. Repeat operations in items 3… 4 of current procedure with span gas in range of 5-100%Vol (recommended in mid of range, e.g. 50% Vol CH4), if sensor has measurement range up to 100% vol. CH4. No need to calibrate second range, it is out of use.

List of CGM used for checking IR gas sensors MIPEX-02

The recalculation to % of LEL shall be effected in accordance with the following formula for concentration expressed in volume fraction, vol. %:

$$LFSCL = \frac{100 \times C}{C(h)};\%$$

where

LFSCL is % LEL

C – component content in volume fraction, vol. %;

C(h) – LEL of component, % (constant);

C(h) = 4.4 % – for methane;

C(h) = 1.7 % – for propane.

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Table 12. CGM used for CH4 calibration gas.

CGM Nos according to text	Component composition	Composition of measured component, vol. %, (% of LEL)	Permissible deviation limits, vol. %	Limits of permissible error of qualification, vol. %	Number as per State Register or Standard designation
1	N_2	100	-	-	GOST 9392-74
2	$CH_4 – N_2$	2,2 (50)	±0,25	±0,04	3883-87
3	$CH_4 – N_2$	4,15 (94)	±0,25	±0,04	3883-87

Table 13. CGM used for C3H8 calibration gas.

CGM Nos according to text	Component composition	Composition of measured component, vol. %, (% of LEL)	Permissible deviation limits, vol. %	Limits of permissible error of qualification, vol. %	Number as per State Register or Standard designation
1	N_2	100	-	-	GOST 9392-74
2	$C_3H_8 – N_2$	0,85 (50)	±0,05	±0,015	5328-90
3	$C_3H_8 – N_2$	1,6 (94)	±0,1	±0,05	EM 06.01.648

Table 14. CGM used for CO2 calibration gas.

CGM Nos according to text	Component composition	Composition of measured component, vol. %, (% of LEL)	Permissible deviation limits, vol. %	Limits of permissible error of qualification, vol. %	Number as per State Register or Standard designation
1	N_2	100	-	-	GOST 9392-74
2	$CO_2 – N_2$	1	±0,05	±0,015	
3	$CO_2 – N_2$	2.5	±0,1	±0,05	

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Appendix E. Dust filters.

The dust filters are available on special request. For the “Standard” and “Plastic” housings is used **Top filter ESAT.717100.001** only (see Fig. 11). For the “Fast response” modification is used additional **Side filter ESAT.717100.002** (see Fig. 12). The filters material - Membrane **Владипор МФФК ТУ 6-55-221-1413-2004**. On the dark areas applied **3M Double Linered Laminating Adhesive 7952**.

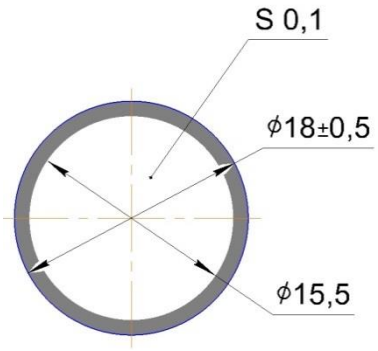

Fig. 11. Top filter for the "Standard" and "Plastic" housings.

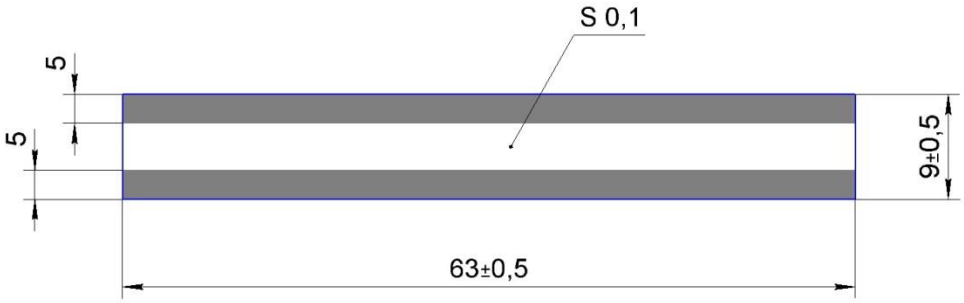

Fig. 12. Side filter for the "Fast response" housing.

To attach the dust filter, perform the following steps:

- Perform this work at well illuminated and well ventilated place.
- After attaching the dust filter, perform zeroing procedure (see Appendix D for details).

- Wipe the sensor top surface with a cloth that is dampened with absolute alcohol. For the “Fast response” modification, perform the same operation on the side surface.
- Retrieve the teflon tape-bonded dust filters from packing.
- Detach a filter from the teflon tape with tweezers.
- Align the filter to the top surface center with tweezers, and then press on it. For the “Fast response” modification, perform the same operation on the side surface.

After the dust filter was attached, zeroing procedure must be performed (see Appendix D for details).

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